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GB 2186981 A WO 91/15738 A1

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(54) Flowrate monitoring apparatus

(57) A flow measuring apparatus (10) for monitoring the flow rates of the components of a multi-phase fluid mixture moving along a flow line, and which comprises a housing (11) having an inlet (12) and an outlet (13), an electrically operated mixture density instrument (14) arranged along the path of travel of the fluid and responsive to variations in relative proportions of the components of the fluid mixture to provide a first signal from which the density of the fluid mixture can be derived, a restriction (16) in the housing through which the fluid mixture has to pass, a differential pressure measurement device (19) arranged to monitor the pressure differential generated by passage of the fluid mixture through the restriction (16) to generate a second signal representative of the pressure differential, and means for deriving from the first and second signals, the relative flow rates of the components of the fluid mixture.

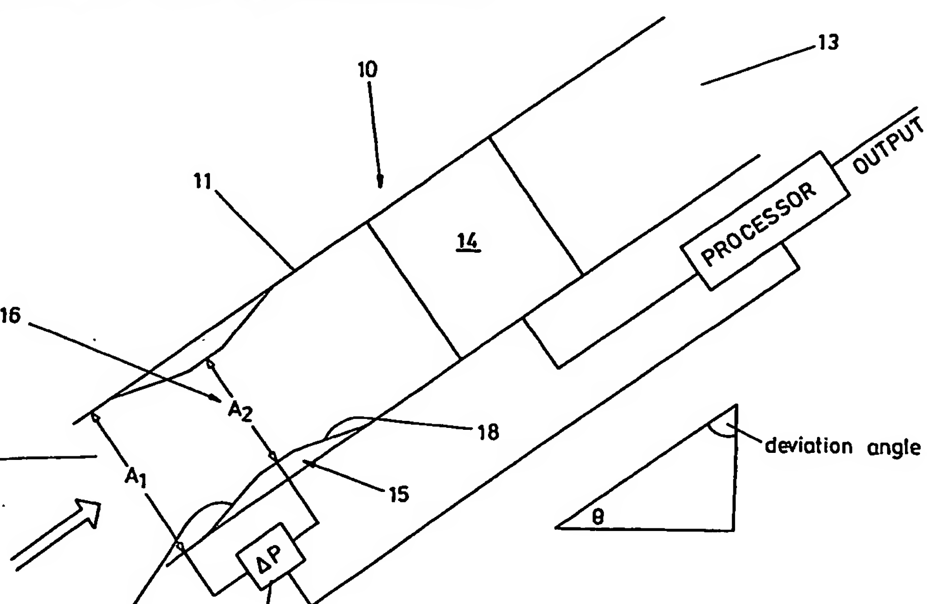

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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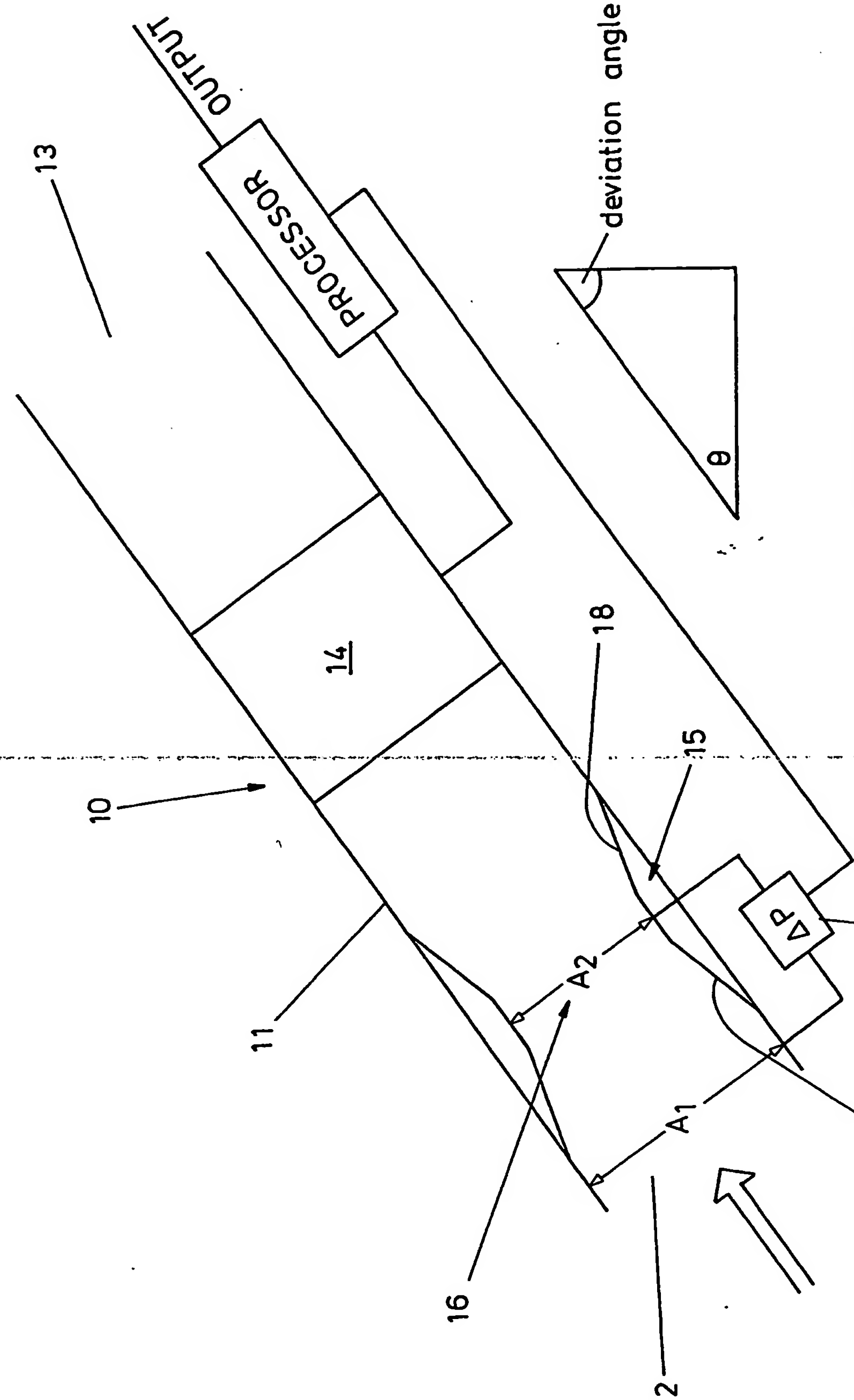

OUTPUT
PROCESSOR
deviation angle
θ
13
14
10
11
15
18
ΔP
19
A2
A1
16
17
12

FIG. 1

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FLOWRATE MONITORING APPARATUS

This invention relates to a flowrate monitoring apparatus for measuring the flowrates of the components of a multi-phase fluid mixture, such as a mixture of water and oil, or a mixture of gas dissolved under pressure in oil, and is particularly, though not exclusively, concerned with apparatus for monitoring the flowrates of fluid hydrocarbon products from a natural underground reservoir.

In the extraction of hydrocarbon products, such as oil or gas from natural reservoirs, it is desirable to know the rate at which the fluids flow through the extraction conduit from the points of view both of management of the extraction operation and of management of the reservoir. Commonly, such reservoirs occur in locations where climate and other factors make management of the extraction process hazardous, such reservoirs generally being underground at elevated temperature and pressure in locations such as desert or subsea. A further complication is that the fluid extracted from natural reservoirs frequently exists in more than one phase, and it can be desirable to know the individual flowrates of the constituent phases. For example, in the case of extraction of oil from a subsea oil reservoir, fluid extracted from the reservoir can contain water and gas in addition to the desired oil. It is known to monitor flowrates of fluids extracted from underground hydrocarbon reservoirs using a testpipe which is laid between the point of extraction from the reservoir (known as wellhead cluster) and a point from which the extraction process is controlled. For example, consider the case where a subsea reservoir is several miles from the rig where the extraction process is controlled. A test pipe is laid from the wellhead cluster to the rig. Products extracted through the testline are separated into oil, water and gas components, and the individual flowrates of th separated components are measured. This technique for measuring flowrates, involving use of a test pipe has several disadvantages. Particularly

significant is the expense associated with laying a dedicated test pipe from a wellhead cluster to a control location, especially when the wellhead cluster is remote from the control location. The accuracy and frequency with which flowrates through a main extraction conduit can be estimated by carrying out measurements at a remote control location using a test pipe is limited.

Furthermore, it is often necessary to pump chemical treatments into the well to, for example, inhibit the formation of scale deposits on the internal surfaces of the production pipe during extraction of hydrocarbon products. Many thousands of barrels of chemical may be displaced into the underground reservoir and present systems use separate monitoring means to measure both the flowrate and cumulative volume pumped of injected chemicals, which of course will flow in the reverse direction to the directions of flow of the extracted hydrocarbons.

The invention has the advantage that information concerning the rate of flow can be provided to operate at the control location, without the need to lay a dedicated test pipe, especially when the wellhead cluster is remote from the control location. The significant expense associated with such a test pipe is therefore avoided. Furthermore, the accuracy and frequency with which the rate of flow of hydrocarbon products from an underground reservoir can be monitored are increased significantly compared with the monitoring process previously used.

The present invention is applicable to monitoring the rates of flow from reservoirs located close to a control location (as in the case with land and platform wells) where the frequency with which monitoring can take place can be a particular advantage. Additionally, the invention can be applied to reservoirs located remote from a control location (as in the case with subsea well cluster) where the frequency with which monitoring can take place, and avoiding the need to lay a dedicated test

pipe, are advantages over previ usly used techniques.

According to the invention there is provided a flow measuring apparatus for monitoring the flow rates of the components of a multi-phase fluid mixture moving along a flow line, said apparatus comprising:

a housing having an inlet for receiving the fluid mixture to be monitored and an outlet for discharging the fluid mixture;

an electrically operated measuring device arranged along the path of travel of the fluid from the inlet to the outlet, said device being responsive to variations in relative proportions of the components of the fluid mixture to provide a signal from which the density of the fluid mixture can be derived;

a restriction in the housing through which the fluid mixture has to pass;

a differential pressure measurement device arranged to monitor the pressure differential generated by passage of the fluid mixture through the restriction, said device being operable to generate a signal representative of this pressure differential; and

means for deriving from the mixture density signal, and from the pressure differential signal the relative flow rates of the components of the fluid mixture.

cap device

The electrically operated device is of a type which is able to respond to variations in proportions of the components of a dual phase fluid, and preferably comprises a capacitive device which gives different measurements according to variations in relative proportions of the two components. However, the invention will include other types of electrical device which can respond to the presence of a dielectric of variable influence depending upon the relative proportions of the components of the fluid mixtures e.g an inductive device. Preferred examples of fluid mixtures with which the invention can be used comprise mixtures of oil and water which are being

conveyed from an underground reservoir to a surface collection installation.

The pressure differential measurement device is arranged to monitor the differential pressure between two sampling positions, either by use of two separate pressure gauges arranged one for monitoring each position, or by use of a differential pressure gauge. The sampling position preferably comprises one at or in the neighbourhood of the restriction, and a further one upstream, or downstream of the restriction.

The electrically operated measuring device may be arranged upstream, or downstream of the pressure differential monitoring device, and may comprise an arrangement of spaced capacitor plates e.g in its simplest form a pair of spaced plates, or a pair of spirally wound capacitors, provided that the flowing fluid mixture flows between and forms a dielectric between the plates whose influence on the capacity will vary with variation in the relative proportions of the components of the fluid mixture.

The products whose flowrate is measured by the apparatus may comprise a gas, liquid, and mixtures of the two. The invention may find application in the extraction of a fluid from a reservoir by injection into the reservoir of another fluid, for example gas or water injection wells. When the products include liquid components, the components may be immiscible, for example comprising oil and water phases. When the extracted products comprise gas and liquid components, it is particularly preferred that a pipe section in which the flowrate apparatus is incorporated be positioned at a location at which the pressure to which the products are subjected is greater than the bubble point pressure of the liquid, so that the products whose flowrate is measured consists only of liquid (which may consist of immiscible components). This makes it possible for the step of separating components of the extracted products into gas and liquid phases, which has taken place at

the control location at the proximal end of the test pipe in previously used monitoring techniques, to be avoided.

The present invention will find particular application in the extraction of hydrocarbon products from underground reservoirs which are located below a seabed. In such applications control locations are frequently provided at some significant distance from the reservoirs in question, making the use of a testpipe between the wellhead cluster and the respective control locations particularly disadvantageous. Furthermore, the pressure to which the extracted products are subjected at the point of extraction is particulary high. This makes it possible for the flowrate of products which include a gas component to be measured on just a liquid phase in which the gas component is dissolved in the manner described above.

In the application of the invention to monitoring hydrocarbon flow rates, there is the significant advantage that the bore through which the hydrocarbon products flow is not obstructed by any component of the apparatus as would be the case if, for example the apparatus comprised an impeller which is caused to rotate by movement of fluid past it. The lack of any obstruction in the bore is particularly significant when, as is generally the case in the present invention, the measurement of fluid flowrate takes place on the pipe through which products are extracted from the reservoir, since it allows access to be gained to the reservoir for example with equipment which might be required for reservoir measurements. A further advantage of the use of such a flowmeter is that, in the absence of moving parts such as an impeller, it is relatively insensitive to rough treatment such as it might be exposed to when incorporated within a pipe section in the vicinity of an underground reservoir. The apparatus is therefore significantly more robust than other designs presently available and would have a longer service life reducing time lost for repairs or replacement.

In operation of the apparatus, it is preferred to measure a permittivity (from the mixture density device) and a pressure differential (from the differential flowmeter). From this information it is possible to determine the individual flowrates of the liquid components (i.e oil and water). This is especially useful for the assessment of multiphase liquids typically found in underground oil reservoirs as it allows the individual flowrates of the phases of the products within the pipe section to be calculated, without any need to separate the individual phases and then calculate the flowrates which is the current practice.

Generally the pipe section of the apparatus has an internal bore which is approximately circular in cross section.

An embodiment of flowrate monitoring apparatus according to the present invention will now be described, by way of example only, with reference to the accompanying schematic drawing of a preferred embodiment of flowmeter comprising a device for measuring mixture density and a differential flowmeter.

Referring to the drawing, this shows an embodiment of flowmeter apparatus 10 according to the present invention which comprises a pipe section or housing 11 having an inlet 12 through which hydrocarbon products are received from an underground reservoir, and are discharged via outlet 13 to a pipe for transportation from the reservoir, for example to the surface if the reservoir is below ground level.

The flowmeter comprises two elements, namely a mixture density instrument 14 and a differential flowmeter 15.

The mixture density instrument is an electrically operated measuring device responsive to variations in relative proportions of the components of a multi-phase fluid mixture and preferable is of the capacitance type. In practice the permittivity of the oil/water mixture is measured. Knowledge

of the individual oil and water permittivities allows the water fraction and hence the mixture density to be determined. This instrument is of a type widely used in surface applications for different purposes.

The differential flowrate instrument consists of a constriction section 16 connected by entry and exit sections 17 and 18. Differential pressure measurement ΔP is made between pipe cross sections A1, A2. this differential pressure, together with the previously determined fluid density being used to determine the flowrates of the individual oil and water phases. The pressure differential can be determined by use of a differential pressure gauge 7 or by the difference between two absolute pressure gauges located at positions 4, 5. Although one pressure tapping is shown upstream of the constriction, it could also be located on the downstream side of the constriction.

It is preferable, though not essential, that the included angles of the entry and exit sections 17, 18 should be relatively small, and preferably should not exceed 15 degrees. This will ensure minimal permanent pressure loss over the device. It will also enable the flowmeter to measure flowrates of fluid in either direction e.g oil/water in one direction or injected chemicals in the reverse direction.

Although the mixture density device is preferably located downstream of the differential meter (in order to homogenise the oil/water mixture) it can also be located upstream.

In practice the differential flowrate and mixture density instruments would be built into a single housing. They could also be separate and connected by a section of production tubing. One significant advantage of this device is that accuracy is independent of well deviation. It can even op rate in horiz ntal wells. This is in stark contrast with previous proposals which will not operate in horizontal wells.

When the products flowing through the pipe section 11 comprise two immiscible liquid phases and a gas component, the pipe section with associated gauges etc will be located such that the pressure under which products within it flow is greater than the bubble point, so that the gas component remains dissolved in the liquid phases. The products flowing through the pipe section past the measurement points are therefore in liquid phases only. The pressure change and mixture density measurements allow the rate of flow of the individual liquid phases to be measured.

EXAMPLE

The relative proportions and flowrates of a two phase liquid extracted from an underground reservoir is calculated as follows, reference being made to the accompanying drawing. In the drawing, the pipe section 11 is inclined at an angle (θ). Upstream of the constriction 15, the cross section of the pipe is A_1, and at the constriction, the cross section of the pipe is A_2. The differential pressure gauge 19 measures a pressure differential ΔP. The distance between the pressure tappings is L.

As a first step the mixture density of the two phase liquid which flows along the pipe is calculated from the following relationship:

$$\rho = f \text{ (mixture permittivity)} \qquad (1)$$

Mixture permittivity is derived from the mixture density instrument 14. Such instruments are widely used in refinery operations. Although the exact form of equation 1 is not presented, it has been previously presented in the literature.

The water fraction (WF) in the mixture can be calculated from knowledge of the density of the mixture together with knowledge of the individual oil and water densities according to the

formula:

$$WF = \frac{\rho - \rho_o}{\rho_w - \rho_o}$$

The total or gross volumetric flowrate (Q) is then calculated according to the following formula:

$$Q = \frac{Cd.A_1.A_2}{\sqrt{A_1^2 - A_2^2}}.\sqrt{2g(\frac{\Delta P}{\rho} - L.\sin\theta)}$$

Cd is the discharge coefficient and g = 9.81 $m.s^{-2}$.

Individual oil and water flowrates (Q_o, Q_w) can now be calculated as follows:

$$Q_o = Q.(1-WF)$$

$$Q_w = Q.WF$$

Using the following values:

ΔP = 1055 $kg.m^{-2}$
ρ_o = 761.3 $kg.m^{-3}$
ρ_w = 1000 $kg.m^{-1}$
L = 0.61 m
A_1 = 0.0195 m^2
A_2 = 0.0046 m^2
Cd = 0.98
θ = 30°
ρ = 941.3 $kg.m^{-3}$

the following values are arrived at:

WF = 0.95
Q = 0.0186 $m^3.s^{-1}$
Q_o = 0.0046 $m^3.s^{-1}$
Q_w = 0.0139 $m^3 \cdot s^{-1}$

CLAIMS

1. A flow measuring apparatus for monitoring the flow rates of the components of a multi-phase fluid mixture moving along the flow line, said apparatus comprising:

a housing having an inlet for receiving the fluid mixture to be monitored and an outlet for discharging the fluid mixture;

an electrically operated measuring device arranged along the path of travel of the fluid from the inlet to the outlet, said device being responsive to variations in relative proportions of the components of the fluid mixture to provide a signal from which the density of the fluid mixture can be derived;

a restriction in the housing through which the fluid mixture has to pass;

a differential pressure measurement device arranged to monitor the pressure differential generated by passage of the fluid mixture through the restriction, said device being operable to generate a signal representative of this pressure differential; and

means for deriving from the mixture density signal, and from the pressure differential signal the relative flow rates of the components of the fluid mixture.

2. Apparatus according to Claim 1, in which the electrically operated measuring device comprises a capacitive device operative to give different measurements according to variations in relative proportions of the components of the multi-phase fluid mixture.

3. Apparatus according to Claim 1, in which the electrically operated measuring device is operative to respond to the presence of a dielectric of variable influence depending upon the relative proportions of the components of the multi-phase fluid mixture.

4. Apparatus according to Claim 3, in which the electrically operated measuring device is an inductive device.

5. Apparatus according to any one of Claims 1 to 4, in

which the pressure diff rential measurement device is arranged to monitor the differential pressure between two sampling positions, either by use of two separate pressure gauges arranged one for monitoring each position, or by use of a differential pressure gauge.

6. Apparatus according to Claim 5, in which the sampling positions comprise one arranged at or in the neighbourhood of the restriction, and a further sampling position upstream, or downstream of the restriction.

7. Apparatus according to any one of Claims 1 to 6, in which the electrically operated measuring device is arranged upstream, or downstream of the pressure differential monitoring device.

8. Apparatus according to Claim 7 when appendant to Claim 2, in which the electrically operated measuring device comprises an arrangement of spaced capacitor plates, or a pair of spirally wound capacitors, arranged such that the flowing fluid mixture can flow between and form a dielectric between the capacitor elements whose influence on the capacity will vary with variation in the relative proportions of the components of the fluid mixture.

9. A method of monitoring the flow rates of the components of a multi-phase fluid mixture including gas and liquid components, employing apparatus according to any one of Claims 1 to 8, in which the apparatus is incorporated in a pipe section which is positioned at a location at which the pressure to which the products are subjected is greater than the bubble point pressure of the liquid, so that the products whose flow rate is measured consists only of liquid.

10. A method according to Claim 9, and used to monitor the extraction of hydrocarbon products from underground reservoirs.

11. A method according to Claim 9 or 10, in which permittivity is measured by the mixture density device and pressure differential is measured by the differential flow meter.

12. A method according to any one of Claims 9 to 11, in

which the pipe section has an internal bore which is approximately circular in cross section.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number: GB 9308829.2

Relevant Technical fields

(i) UK Cl (Edition L) G1R - RG

(ii) Int Cl (Edition 5) G01F - 1/74

Search Examiner: B F BAXTER

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Date of Search: 29 JUNE 1993

Documents considered relevant following a search in respect of claims 1-12

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2186981 A (PRAD RESEARCH AND DEVELOPMENT) whole document	1
X	WO 91/15738 A1 (AGAR) whole document	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

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